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POLICY BRIEF

Gender Mainstreaming in Sustainable Agricultural Mechanization 2024

Developing and Scaling Gender-Responsive Mechanization

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I. Why Consider Gender-Responsive Mechanization?

1.1 Women in Agrifood Systems

Women smallholder farmers are key actors in the agrifood system - they are producers, processors, laborers, traders, and consumers.[1] In many countries agrifood systems are a more important source of livelihood for women than for men, with women representing 60-80% of smallholder farmers globally and contributing to 43% of the world's food production.[2] In South Asia, women form 71% of the agrifood system labor force.[3] Despite women's critical roles in agrifood systems, they tend to be marginalized and lack access to resources and services including agricultural technologies and mechanization, extension services, land rights, better inputs, and finance. This inequity in women's access to resources has resulted in a "gender yield gap" with women farmers achieving 24% lower yields than male farmers.[4]

Empowering women and closing gender gaps in agrifood systems does not just help towards achieving Sustainable Development Goals, but also leads to better food and nutrition security at the household level and results in resilient and sustainable food systems overall. FAO's 2023 Status of Women in Agrifood Systems report states that closing the gender gap in farm productivity and the agricultural wages gap in agrifood systems can help reduce the number of food-insecure people by 45 million. Additionally, even if half of all small-scale producers benefitted from women's empowerment interventions, this could lead to increased incomes for an additional 58 million people and improved resilience for an additional 235 million people.[5]

1.2 Changing Contexts

The outmigration of men and youth from rural areas in search of lucrative off-farm opportunities are changing household roles, resulting in women taking on additional responsibilities both on the farm and in the household. For instance, in Nepal and Viet Nam, male outmigration is leading to a scarcity in agricultural labor. Women who remain continue to carry out tasks ascribed to women such as sowing, weeding and livestock care in addition to taking on "men's work" such as land preparation, dike building, irrigation, fertilizer and pesticide application. This increase in women's workload and farm managerial responsibilities coupled with heightened costs for hiring labor has led women to adopt less intensive farming practices and, in some cases, leave cultivable land fallow.[6]

Nevertheless, in certain contexts, this "feminization of agriculture" is increasing women's decision-making power and providing opportunities to attend trainings and learn about new technologies.[7]

[1] Njuki et al. (2021)
[2] FAO (2011); FAO (2023)
[3] World Bank data
[4] FAO (2023)
[5] Ibid.
[6] Farnworth et al. (2021); Farnworth et al. (2019); Paudel et al. (2020); Paris et al. (2009)
[7] FAO (2023)

Feminization of agriculture is further driven by the increasing severity of the climate crisis, conflict, and shocks such as COVID-19.[8] Although climate change related threats including increasing temperatures, changes in seasonal rainfall patterns, and extreme weather events such as droughts and floods are affecting production systems and livelihoods globally, the effects are worse for women smallholder farmers. A higher proportion of women smallholder farmers are directly dependent on agriculture for their livelihoods, and they tend to be more exposed to climate change risks due to limited access to assets and resources required to absorb shocks, adapt, and build resilience.[9] Supporting climate resilient agrifood systems is critical to build the resilience of smallholder farmers; and there is an urgent need to ensure women farmers can access the sustainable agricultural mechanization and knowledge needed to benefit from such systems.[10]

1.3 Gendered Challenges to Mechanization

Sustainable agricultural mechanization can contribute to the sustainable development of agrifood systems by improving farmer's livelihoods. Mechanization can relieve labor shortages, save time, reduce drudgery, ensure efficient use of resources, enhance agricultural productivity, and make farming more profitable.[11] Additionally, climate smart technologies such as drip irrigation systems coupled with harvesting and drying equipment can help smallholder farmers build resilience by adapting to climate change effects.[12]

Mechanization can benefit women smallholder farmers immensely. For instance, Labor Saving Technologies (LSTs) can reduce the heavy toil of farming often borne by women and children who provide unpaid family labor.[13] LSTs can also empower women by reducing their dependence on men for labor allowing them to engage in producing high value crops.[14] Yet, agricultural technologies and mechanization are not gender-neutral; and despite the advantages, women continue to lag behind men in their ability to access, adopt, own, and benefit from mechanization.[15] Research shows that the rates of agricultural technology adoption among women are significantly lower than their

Box 1: Defining agricultural mechanization

While agricultural mechanization is often equated with tractors and big machinery, it comprises of technologies that address needs across the agricultural value chain from production to post-processing. This includes equipment for land preparation, planting, weed control, fertilizer application, harvesting, and postharvest activities including storage and on-farm processing. Agricultural Mechanization includes:

- Simple hand tools and technologies that use manual strength or draught animal traction
- Labor saving technologies such as direct drum seeders, portable reapers, laser land deleveling, shellers, grain dryers
- Irrigation equipment and systems
- Motorized equipment that run on fossil fuels or renewable energy such as combine harvesters
- Climate-smart agriculture equipment such as no-till planters

Note: In this paper the term "technologies" and "mechanization" are used interchangeably.

Sources: FAO What is Sustainable Agricultural Mechanization. Daum (2023)

[8] Ibid.
[9] FAO & CARE (2019); Koo et al. (2022)
[10] CCAFS (2015); FAO (2022) Women farmer's access to SAM; FAO & CARE (2019)
[11] Daum (2023); FAO & AUC (2018)
[12] Alam et al. (2019); Daum (2023)
[13] Daum (2023); FAO (2023); Vos & Takeshima (2022)
[14] FAO (2023); Vemireddy & Choudhary (2021)
[15] FAO (2011); Grassi et al. (2015); McGuire et al. (2022); Polar et al. (2015); Rola-Rubzen (2020)

male counterparts.[16] This is further compounded in the case of female headed households who tend to have less access to mechanization as compared to men.[17]

Gendered challenges to mechanization exist both at a user and at a systemic level

At a user level both men and women face constraints in adopting new technologies, but women face additional barriers. There is a dearth of technologies adapted for women that considers the nature of their work, their time use, their physique, and the socio-cultural context they live in.[18] Even when technologies exist they may not be accessible for women due to lack of resources and can unintentionally create issues such as imposing additional time and drudgery on women or displacing their income or livelihoods.[19] Gendered constraints to adoption can vary by crop, value chain, region, country, socio-economic status, and intersecting identities such as religion, caste, and age. Even when women have the interest and willingness to adopt technologies or hire custom mechanization services gender dynamics and social norms can limit their ability to use or hire and benefit from beneficial technologies.[20]

Additionally, to scale women's adoption of beneficial technologies we need to not only address user's constraints but also address barriers and enablers across the agrifood ecosystem. Currently, agricultural innovation programmes tend to be primarily directed at middle-income male farmers;[21] and scaling processes do not address women's challenges in learning about the technology, affordability, access to complimentary resources such as credit, and access to services such as repair or maintenance.[22] Men and women smallholder farmers are equally likely to adopt new technologies when the necessary enabling factors are put in place; therefore, better policies, investments and interventions are needed to ensure upstream innovations reach and benefit the women users downstream.[23] This includes addressing gender gaps within the mechanization value chain and the enabling environment in partnership with stakeholders such as the private sector, research institutions, civil society organizations, donors and the public sector.

[16] ADB (2012); Doss & Morris (2001); Huyer & Chanana (2016); Rola-Rubzen (2020)
[17] Bryan et al. (2023); Daum (2023)
[18] Grassi et al. (2015)
[19] Kosec et al. (2023); Tarjem et al. (2021)
[20] Farnworth et al. (2016); FAO (2023); Mutenge et al. (2019); Theis et al. (2019)
[21] CYMMIT (2022); Manfre et al. (2017)
[22] FAO (2021); McGuire (2022); Vemireddy & Choudhary (2021)
[23] Bain & Company (2014); FAO (2023)

II. Developing Gender-Responsive Sustainable Agricultural Mechanization

To ensure that sustainable agricultural mechanization truly benefits both men and women smallholder farmers, we need to develop and scale gender responsive technologies. Gender responsive sustainable agricultural mechanization goes beyond the identification of gender-based differences and makes a conscious effort to address the needs, priorities, preferences and realities of men and women in the technology's design and scaling processes. This involves understanding and addressing gendered constraints in a technology's design, dissemination processes and in increasing adoption. It also involves anticipating how technologies can affect women and men differently to ensure that both can benefit in the immediate and long term, and neither are harmed.[24]

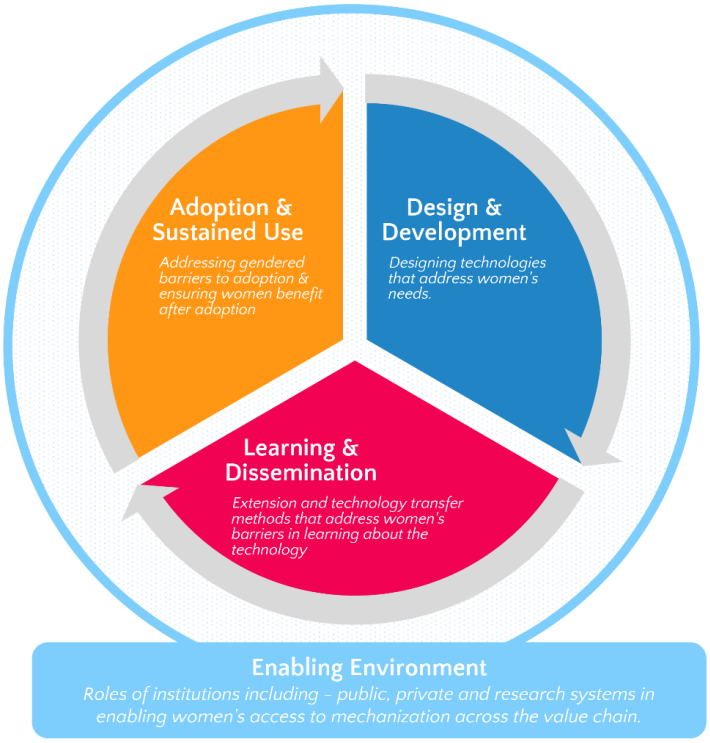

Figure 1: Gender Responsive Mechanization Development Framework Adapted from Manfre et al. (2017) & Theis et al. (2018)

The **Gender Responsive Mechanization Development framework** can help systematically understand and address gendered constraints across a technology's adoption and scaling pathway. Adapted from the "Guidance for inclusive irrigation interventions"[25] and the "Technology assessment toolkit"[26] this framework comprises of four components:

1. Designing and developing mechanization that addresses gendered needs
2. Technology dissemination and transfer methods that address gendered barriers in learning
3. Facilitating initial adoption and sustained use of mechanization by addressing gendered barriers in adoption, and ensuring women continue to benefit after adoption

[24] Nelson & Huyer (2016).
[25] Theis et al. (2018)
[26] Manfre et al. (2017)

4. Engaging institutions including the public, private and research systems in enabling women and men's access to mechanization across the value chain.

2.1 Design Technologies with Women at the Centre of the Innovation Process

Women and men have different agricultural technology and mechanization requirements. However, most technologies are largely "built for and by men" resulting in an invisible bias impacting women users.[27] Women are often not consulted during technological innovation development process, and hence their voices, needs and preferences are not reflected in the design, deployment, and evaluation of agricultural technologies. This has resulted in many machines being inappropriate for women, difficult to operate, contributing to low levels of adoption among women.[28] To develop gender-responsive agricultural technologies and mechanization, we need to start by designing for and with women as users at the centre of the innovation development process. This includes engaging users from upstream planning, priority setting to co-designing and in implementing new solutions.[29]

To achieve this, the first step is to understand women's mechanization needs using a bottom-up or user-centric approach where engineers and designers listen to women users and seek to understand their needs and preferences. Prior to designing the technology, technology developers need to identify critical gender gaps and constraints in technology access, understand barriers in technology use, management, and key formal and informal services such as information, repair and maintenance, training, financial and business development services.[30] Moreover, these gaps need to be identified in place-based conditions so that the solutions developed not only address the user's needs, expectations and capabilities but also recognize the influences of culture, politics, education, technical receptivity and economic need.[31] Human centred design[32] principles and participatory innovation development[33] are examples of methodologies that can help technology developers think about gendered needs and constraints by considering input from both female and male users. Existing tools such as the 'gender-responsive needs assessment for mechanization' developed by FAO can also be beneficial to identify women's needs and constraints.[34] More tools to help guide researchers and technology developers assess, design and scale gender-responsive agricultural technologies and mechanization can be found in table 1.

2.1.1 Design for Women's Roles in Agriculture

Smallholder women farmers face a triple burden in the productive, reproductive, and social spheres. This triple burden results in simultaneous competing claims on women's time leading to time poverty and work overload that restricts their well-being and engagement in activities of value, including income generating activities.[35] Moreover, there are

[27] Perez (2018)
[28] Tarjem et al. (2021)
[29] Gadeburg (2023)
[30] FAO (2021)
[31] Witmer-Perry (2018); Witmer-Perry (2020)
[32] IDEO.ORG (2015)
[33] FAO & CARE (2019)
[34] FAO (2021).
[35] Grassi et al. (2015)

gendered patterns of cropping which vary with participation in different agricultural value chains or even within the same value chain.[36] The gendered division of labor is also dynamic with variations by region, farming system, and shifts with changes in seasons, markets, and climate. This results in women and men having different sets of needs and priorities for mechanization.[37] LSTs can help smallholder farmers reduce time and energy spent, increase agricultural productivity, reduce cost of production and processing, and save on scarce resources including labor and energy;[38] however, they have often neglected women-led production processes (such as weeding, post-harvest processing) and activities associated specifically with women's work (such as home gardens).

Box 2. A universal problem

This widespread lack of customized machines and equipment for women is not unique to agricultural technologies promoted within smallholder farmers in low- and middle-income contexts, but also present in higher income countries. Lack of products designed for women is pervasive in the design of other technologies such as car safety mechanisms, public bathrooms, electronics, and even medical devices. It is also important to note that by designing technologies beneficial for women it can also benefit men who are not represented by the standard references used in developing technologies.

Sources: Yoder et al. (2010); Perez (2021)

Engineers and designers can develop gender responsive mechanization that target women's current roles and responsibilities in agrifood systems by catering to women-led production processes, activities, priorities, and considering when women's labor peaks occur.[39] For example, the International Rice Research Institute (IRRI) has strategically addressed gendered technology needs by developing and promoting mechanization that addressed women's agricultural roles in Bangladesh and Viet Nam. In Bangladesh, IRRI introduced a portable rice flour mill to reduce women's drudgery and increase their access to rice processing as an income generating activity. A participatory evaluation of the technology showed that the machine was technically efficient, economically viable, and socially acceptable among women operators and sellers of rice products. The machine also provided women rice flour operators with an income, developed women's self-esteem and social status, and empowered them to make their own decisions in spending their earnings.[40] Similarly, in Viet Nam, IRRI promoted the plastic drum seeders to enable women farmers to sow rice seeds directly instead of broadcasting or transplanting rice seedlings. The drum seeder vastly reduced women's time spent on tasks such as gap-filling and hand-weeding, lowered production costs through reduced use of seeds and labor and produced higher yields. The seeder resulted in women having more time for childcare, income-generating activities, and community activities, although it primarily only benefited women from better-off households.[41] See table 2 for a brief list of LSTs tested or designed for women smallholder farmers in Asia.

2.1.2 Design for Women's Preferences

Technology attributes or characteristics play a critical role in their adoption or non-adoption by men and women.[42] Most agricultural tools and equipment are designed for men's physiques and ergonomic factors; and anthropometric human factors studies that ensure machines or tools are suitable and safe

[36] Doss (2002)
[37] Manfre et al. (2017); Tian (2019)
[38] Ragasa (2012)
[39] Grassi et al. (2015)
[40] Paris et al. (2011)
[41] Carr & Hartl (2010)
[42] Polar et al. (2017)

for people are based on standard male body dimensions including height, strength, and body type. Unfortunately, a universal technology design doesn't serve everyone equally and results in hard to use agricultural tools leading to low adoptions by women or safety issues from incorrect handling.[43]

We need to design for women's preferences by intentionally considering technology design factors such as ergonomics, ease and simplicity in operation, cultural appropriateness in use, and technology use-case factors. Engineers and technology designers need to consider that women are not just smaller men; for instance, women have a lower centre of gravity that results in better balance than men and greater flexibility which should influence technology design.[44] Other features to be considered while designing agricultural implements for women include:

• Designed to utilize lower body strength: Anthropometric studies have found that women have 40-75% less upper-body strength and 5-30% less lower-body strength compared to men.[45]

• Designed with smaller handle grips. Women tend to have smaller grips, which can result tool grips designed with men's ergonomics being too big for women's hands. This can cause the tool to slip, strain muscles, and place women at risk of an injury.[46]

• Designed in multiple sizes. Women tend to have smaller stature (shorter arms & legs) and smaller grip. Incorrect tool height or sizing can require more physical labor, cause pain and result in muscular strain. For example, the short-handled hoe is commonly used by women in manual planting and weeding requires women to be stooped or hours resulting in fatigue and backpain for women.[47]

• Design lightweight implements: Lighter weighing implements are better suited for women's needs and minimize physical energy or effort needed. For

Box 3: A successful example of engaging women smallholder farmers throughout the innovation development process is FAO's Technical Cooperation Programme project implemented with the Department of Agriculture in Nepal with the aim to scale women's access to sustainable agricultural mechanization. The project placed women farmers at the centre of the decision-making process by conducting a gender-sensitive assessment of targeted cropping systems and districts to select sustainable agricultural tools, machinery and equipment that would reduce drudgery. Insights were used to introduce appropriate technologies for crop production, protection, and postharvest activities; and were locally sourced to reduce farmer's dependence on expensive products and risk of debt. Machines included two-wheel tractors and trailers, mini-tillers, planters, transplanters, weeders, reapers, mobile thresher, de-huskers, and solar dryers. The programme considered contextual gender norms and enabled women's access to mechanization as operators of machinery or service providers offering mechanization services for income generation. Additionally, the programme provided capacity building trainings and established custom hiring centres managed by women that also served as extension enterprises for farmers to observe, test or use machinery. The programme substantially increased the use of improved machinery by women, reducing their workload, lowered production costs and led to an increase in income that had a positive impact on women's empowerment.

Sources: FAO (2022) Women farmer's access to sustainable agricultural mechanization, Nepal; FAO (2022) Technical support for sustainable agricultural mechanization of smallholder farms.

[43] Carr & Hartl (2010); Perez (2021); Yoder et al. (2010); Majumder & Shah (2017)
[44] Reuther (2022)
[45] Yoder et al. (2010)
[46] Women, tools, and ergonomics (2017)
[47] Harrigan & Jones (2020)

example, developing hoes of different weights including very light ones that are better suited to women's needs.[48]

The Indian Council of Agricultural Research (ICAR) Central Institute of Agricultural Engineering analyzed anthropometric data on Indian women's ergonomics including height, weight, strength parameters (push / pull strength), work posture, etc. and carried out ergonomic evaluations of agricultural hand tools and equipment. Based on the assessments ICAR has developed a database of improved tools that have been improved for women's needs. For example, a portable groundnut decorticator designed to be operated by women farmers can be operated in a sitting posture set on ergonomically guidelines and has appropriate dimensions for seat height, length of handle grip, length of handle movement and strength required to operate it.[49] ICAR has also developed design specifications for tractors that accommodates 90% of male and female operator parameters for tractor controls such as hand- and leg-reach envelopes, height of the controls from the seat enabling easier and safer operation.[50] Similarly, Green Heron, a small women-owned business in the United States of America, developed hand tools specifically designed for women labeled as Hergonomic®. Through input gathered from women farmers and with repeated testing, the new agricultural implements were developed in multiple sizes, appropriately balanced, and have patented women-friendly handle grips.[51]

2.1.3 Test with Women Users

Gender responsive technology development requires iterative testing and feedback loops with women users; and this can be achieved with early and better linkages with researchers, extension agents, and other innovation actors. Testing with women users and getting user feedback can reveal key concerns with usability, safety, and cultural appropriateness. For example, a study with silage choppers in Uganda found that women were afraid to use the chopper because of safety concerns despite its benefits in reducing drudgery associated with manual chopping. This limited their ability to venture into silage making on their own since they had to depend on men to operate the machine. Similarly, in Kenya, women users reported difficulty with the treadle pump because it required two people to operate the pump and, in some areas, it was culturally inappropriate for women to operate the pump.[53]

2.2 Cater to Women's Information Needs

Farmer's decision to adopt a new technology requires three types of information: awareness of the availability of a technology, understand the benefits of the technology, and the know-how to effectively utilize the technology.[54] Relevant and timely information can increase farmer's awareness on technologies, assess their usefulness (risk vs. profitability), understand how to acquire them and how to use them.[55] Such information comes from various sources including - traditional agricultural extension services by extension workers, private sector marketing, and farmer's own experiences shared within social networks

Agricultural Extension and Advisory Systems (EAS) play a crucial role in the dissemination and adoption

[48] Carr & Hartl (2010)
[49] Mehta et al. (2018)
[50] Potdar et al. (2022)
[51] SBIR (2016); Squire (2021); Yoder (2010)
[52] Kawarazuka et al. (2018)
[53] Njuki et al. (2014)
[54] Agricultural Technology Adoption Initiative (2016)
[55] Agricultural Technology Adoption Initiative (2016); Theis et al. (2019)

of new technologies and mechanization. Through "train and visit" events, technology demonstrations in the field, farmer field days, and farming shows, EAS have the potential to facilitate technology transfer and management at a low cost to the farmer and can serve as channel relaying farmer needs back to innovators and policymakers.[56] However, traditional extension systems are not gender equitable, and globally, women only receive between 2-10% of all extension contacts and 5% of extension resources worldwide.[57] This gender gap in access to EAS can lower adoption of key technologies by women and is worse for female headed households.

Women face multiple barriers to accessing information and extension services. Firstly, EAS often tend to perceive men as farmers and women as "farmers' wives". Extension agents prefer to work with farmers who control household economic resources and decision making who are often male.[58] Moreover, criteria to participate in trainings on new machines and technologies often exclude women by only targeting the heads of the household who tend to be men.[59] In many contexts, men do not discuss production decisions with their wives or transfer extension knowledge to them resulting in women being left behind.[60]

Secondly, extension services are rarely tailored to address women's needs, priorities, and roles in agriculture resulting in information that may not be beneficial to women. Thirdly, extension events do not consider women's time and mobility constraints which can limit the number of women who can participate in trainings.[61] Women have higher time burden that reduce their incentives to participate in training activities. Moreover, women's mobility constraints can impact their ability to travel far from home for trainings.[62]

Fourthly, women's lower literacy levels can inhibit their access to information. Education and literacy levels determine farmers' ability to understand and manage unfamiliar technology and can affect women's willingness to participate in extension and training activities.[63] Globally, women tend to have lower education and literacy levels which includes not only the ability to read and write but also functional skills, financial literacy, and digital literacy.[64] Additionally, lower education levels have also been related to lower confidence and self-esteem which can limit the adoption of technologies and mechanization that require investment or special operation.[65]

Finally, the way information is presented is just as important as the content. This includes details such as who provides information, what content is delivered, and in what form. At an organizational level, traditional extension systems are male dominated and there are comparatively few women extension agents.[66] Especially in cultures with conservative socio-cultural norms, the practice of female seclusion limits women from interacting or learning from men not within the family thereby hindering women's access to information from traditional EAS.[67]

2.2.1 Conduct Gender Sensitive Technology Training

To ensure that women smallholder farmers have the

[56] Anderson & Feder (2007); Kelsey (2013)
[57] FAO (2011); Ragasa (2012)
[58] Lee et al. (2022); Meinzen-Dick et al. (2010)
[59] Manfre et al. (2013); Rola-Ruben (2020); Farnworth & Colverson (2016)
[60] Ragasa et al. (2014)
[61] FAO (2016)
[62] Ibid.
[63] Ruzzante et al. (2021); Ragasa et al. (2014); Van eerdewijk & Danielsen (2015)
[64] Stewart & Yap (2020)
[65] Ragasa (2012); Viswanathan et al. (2010)
[66] Manfre et al. (2013)
[67] Theis et al. (2019)

information to adopt new technologies, we need to address women's barriers to learning about new technologies. Below are seven strategies.

1. Trainings need to intentionally target women. Training providers should be cognizant of participation criteria and ensure they do not unintentionally exclude women by inviting only head of the household. For instance, a mini-tiller adoption study in Nepal showed lower adoption rates by female headed households compared to male headed one with a key reason being that female headed households were not targeted by extension services for the new technology.[68] When inviting women participants for trainings, it is important to link women's participation and the development of their knowledge and skills to the wider goals of the whole family such as increasing household income.[69] Additionally, set targets for women's participation in technology training events from both male and female headed households.

2. Use gender-sensitive training logistics.

(a). Trainings need to be held at a time suitable for women. This includes time of day, production season, and training duration. For instance, trainings held before noon can conflict with women's responsibilities at the household and the farm. Similarly, trainings during the busy harvest season or immediately right after harvest can prevent women from participating. It is also important to keep training times short to 1-2 hours.[70]

(b). To encourage women's participation, trainings need to be close to the homestead or address women's mobility barriers by providing transportation options. Additionally, providing childcare and sanitation facilities at the training location can make a difference in women's participation.

3. Based on context, consider single-sex groups. There are pros and cons to trainings in mixed groups or women-only groups.[71] However, based on the context, women-only groups and training events can address social barriers that women face (such as asking questions in front of men) and have been shown to build confidence and leadership skills among women.

4. Ensure relevancy of content. Tailored information can be effective in changing practices and improving technology adoption.[72] It is important to tailor information to women farmer's needs, crops that they produce, and women's roles in agriculture such as specific production or postproduction tasks or activities that women control.

5. Utilize accessible training methods. Participatory training methodologies that use adult learning principles can help account for lower literacy and education levels. This includes using facilitated discussions, group activities, demonstrations, and visual aids such as illustrations, pictures, or videos to communicate difficult concepts.[73]

6. Invest in female trainers. Women agents in extension systems and female led training can increase women's participation in extension events. Female extension agents can also address socio-cultural barriers that prevent women from interacting with men beyond immediate family members and make women more comfortable.[74] One study found that female extension agents were able to have more inter-personal communication with women farmers by meeting them at home when they were engaged in household chores.[75]

[68] Farnworth et al. (2021)
[69] Farnworth & Badstue (2017)
[70] Ibid.
[71] Manfre et al. (2013)
[72] Caldwell et al. (2019)
[73] Manfre et al. (2013)
[74] Medendorp et al. (2022)
[75] Digital Green (2021)

7. Collect feedback on engagement by gender. By collecting sex-disaggregated data on participants engagement and usefulness of the training, providers can incorporate feedback into future training designs or other dissemination.

2.2.2 Utilize Women's Information Delivery Networks

Information networks are important for building awareness of specific technologies, minimizing perceived risk, and driving adoption.[76] Long-term technology adoption studies among smallholder farmers have shown that social networks are key to adoption and provide means to participate in agricultural projects and programmes.[77]

Additionally, farmers are more likely to follow advice from someone similar to them or from people within their network and learn from observing the decisions and through positive "word of mouth" information from their social networks.[78]

To target women smallholder farmers with information on new technologies technology developers need to work with women's trusted sources of information and be cognizant that it might differ from men's social networks which women tend to be excluded from. Additionally, women focused Farmer Producer Organizations (FPOs) or farmer groups or Self-Help Groups (SHGs) can also address gendered barriers in accessing information, serve as a trusted channel for information dissemination and increase adoption of agricultural technologies.

2.2.3 Enable Last Mile Delivery through Digitization of Agrifood Systems (D4AG)

The exponential growth and adoption of mobile phones and smart phones coupled with investment in digitization of agrifood systems (D4AG) has resulted in numerous innovations; and digital delivery of information can be an effective strategy to address barriers smallholder farmers face in adopting technologies by improving access to

Box 4: Digital Green Uses A Community-Based Video Approach With Shgs To Target Women Farmers With New Agricultural Practices And Technologies.

This D4AG non-profit organization uses a proven video-based extension model as a low-cost yet effective medium to disseminate information on new agricultural technologies and practices. The videos are tailored to the audience, produced in the regional language, locally relevant and easy to comprehend while being scientifically accurate. Digital Green ensures gender-responsiveness by incorporating interests of both women and men in their videos. Moreover, they include local women as role models and decision makers and demonstrate dialogue and decision making between spouses. The organization improved women farmer's participation rates in their trainings when they shifted training times to the time of day when women farmers were able to attend. They also observed an increase in women's participation, engagement, and adoption of recommended practices when they had women extension agents. Additionally, they ensure that both the men and women extension agents (42% of extension workforce) are trained in understanding gender dynamics. Digital Green also established data collection protocols to gather sex disaggregated data on farmer reached, content uptake, adoption of recommendations, and ease of access to understand and focus on approaches that worked best.

Sources: Digital Green (2021); IDinsight (2021)

[76] Agricultural Technology Adoption Initiative (2016)
[77] Ravula & Bantilan (2007)
[78] Bridle et al. (2020); BenYishay et al. (2015); McGrath et al. (2021)

information, financial institutions, and markets.[79] It can also improve upon traditional extension by customizing the training message, increasing points of contact with farmers, and providing information when farmers need it during the agricultural cycle.[80]

While D4AG solutions can reach women better by avoiding constraints posed by traditional extension systems, it is important to note that there is a gender digital divide. Women and men's access to and use of mobile phones and internet varies by country and region. Currently, 77% of women in South Asia have access to mobile phone, however only 46% use mobile internet and this is lower in rural households where women are unlikely to own their own mobile phone.[81] In instances where they do, it is likely to be a household asset.[82] Literacy levels can also affect women's ability to benefit from digital information.[83] Other digital modes of information that have been successful in reaching lower literate populations include facilitated video dissemination, Interactive Voice Response, radio and TV programmes.

2.3 Address Gendered Barriers to Technology Adoption and Sustained Use

Technologies that are well designed but fail to understand farmers' situations, including their farming systems, their socioeconomic conditions, and their cultural circumstances can fail adoption.[84] Therefore, it is important that thought is given to how mechanization or technologies are introduced, the measures and support that are needed for their adoption, and how gendered challenges in the different phases of adoption can be addressed.[85] Technology adoption occurs in three phases: awareness, initial try out and continued use.[86] While both men and women face challenges in adoption, each of these phases present unique gendered challenges. Awareness is a pre-requisite for initial adoption; however, awareness alone is insufficient to lead to initial adoption or continued use.

If the technology is beneficial for women, initial adoption (trying out) is impacted by access to and control over resources required to use the technology such as land, water, inputs, labor, other assets, or complementary technologies. Initial adoption is also limited by affordability and access to capital or credit to invest in technology.[87] Even after the initial try-out, if the innovation does not meet the needs of users or deliver results they may be abandoned or set aside.[88] Consequently, continued use of a technology is dependent on long-term usefulness, appropriateness of design such as its suitability for women's specific agricultural tasks and physical requirements.[89] Moreover, intra-household relations and broader contextual socio-cultural norms or cultural acceptability play a critical role in continued use of a technology and can determine who reaps the benefits.

2.3.1 Land Ownership as a Factor in Technology Adoption

Evidence shows that when women have secure land rights, land is used more efficiently, agricultural

[79] Caldwell et al. (2019); GSMA (2023), Boettiger & Sanghvi (2019)
[80] Bridle et al. (2020); Cole & Fernando (2012)
[81] GMSA (2023)
[82] Valenti (2020)
[83] Ragasa (2012)
[84] Rola-Rubzen et al. (2020); Witmer-Perry (2020)
[85] Grassi et al. (2015)
[86] Theis, S., Lefore, N. et al. (2018)
[87] Doss (2001); Theis et al. (2018); Ragasa et al. (2015)
[88] IFPRI (2013)
[89] Theis et al. (2018)

investment and production increase, and there are associated beneficial welfare effects.[90] However in Asia, women only comprise 11% of land holders despite forming a significant share of agricultural labor force.[91] Women's land ownership is influenced both by official and unofficial legal structures and social norms; which results in women owning less land area, land that tends to be less fertile, and gets less attention.[92]

Land ownership impacts both male and female farmer's decisions on crops grown (for subsistence or commercial purposes), investing in technologies that require longer-term commitments to see benefits (such as irrigation infrastructure), or adopt profitable but risky new practices and related mechanization that contribute towards the long-term wellbeing of their land (such as conservation agriculture).[93]

Women's sole or joint ownership and control over the land impacts the decision to invest in agricultural technologies due to perceived stability.[94] In many instances, land tenure is required to participate in farmer cooperatives or access extension services making most women ineligible.[95] Furthermore, land ownership status also affects women's access to avail formal credit since land titles are often used as collateral to finance the adoption of new technologies.

Box 5: Complementary innovations are technologies or inputs that allow the core innovation to have impact at scale.

They include:
Resources: Land, inputs, sufficient liquid cash, assets such as farm animal power, access to low-cost fuel, access to credit or financial services.
Infrastructure: Access to electricity or generators (and fuel), roads for mechanization to reach farms.
Services: Ability to access Services locally including operation, repair, and maintenance
Skills: Knowledge of machine operation, basic repair, and maintenance.

Access to complimentary technologies is necessary to scale adoption of core innovations. For example, adoption of a mechanized rice transplanter (core innovation) which can reduce women's time burden and lessen drudgery associated with manual transplanting cannot occur without the complimentary innovation of mat-type nursery bed and technical skills needed to raise seedlings on the mat-type nursery bed. Similarly, a portable mechanized grain dryer (core innovation) that can reduce women's time and labor in grain drying requires access to LPG or charcoal for a fuel source and a stable connection to the electrical grid or a diesel operated generator to power the blower (complimentary innovations). Mechanization promoters need to take complimentary innovations needed into account, and women's access to them prior to developing scaling plans.

Sources: McGuire et al. (2022); Sartas et al. (2019).

2.3.2 Importance of Access to Financial Credit to Scale Adoption

Smallholder farmers require access to financial resources, whether in the form of credit, microfinance, savings products to purchase inputs, technologies, and hire labor. Agricultural technologies such as tractors, plows, and other machinery are capital intensive and access to finance is considered as a major constraint in adoption.[96] A farmer's ability to obtain credit may be correlated with land tenure, agricultural productivity and tied to the lender's perception of the farmer's ability to repay the loan.[97] The ensuing liquidity

[90] Doss (2001), Meinzen-Dick et al. (2019); Rola-Rubzen et al. (2020)
[91] USAID (2019)
[92] Doss (2001); Meinzen-Dick et al. (2019)
[93] Burchardi et al. (2020); Doss (2001); Smucker et al. (2000)
[94] Smucker et al. (2000)
[95] Meinzen-Dick et al. (2019)
[96] Doss (2001); Van Eerdewijk & Danielsen (2015)
[97] Doss (2001)

constraints coupled with lack of affordable technologies, and women's lesser income and asset holdings results in their lower adoption of beneficial technologies.[98]

Women receive less than 10% of available credit since formal credit lending organizations are more likely to provide loans to large scale farmers than small scale or resource poor farmers who are often women.[99] Women resort to informal lending even with its high interest rates due to easy accessibility, timely access and ability to procure in small amounts.[100] While access to microfinance and village level savings and lending groups can be beneficial, it leads to women receiving smaller loan amounts than men and being underrepresented in programmes that finance larger loans.[101] Moreover, in some contexts, women cannot apply for credit without their husband's permission.

Subsidies and rental markets (custom service providers) make mechanization more affordable for smallholder farmers and increase adoption by reducing the cost of capital. Additionally, flexible financing schemes such as pay-as-you go models are also beneficial. However, such arrangements need institutions to facilitate women's access through gender-responsive financial products that are appropriate and sustainable in the long term.[102]

2.3.3 Impact of Intra-Household Power Relations on Technology Adoption

Intra-household power relations or broader social norms can determine how the technology's associated costs and benefits are distributed in the household, which consequently can constrain women's ability to benefit from new technology. The costs and benefits can be understood in the "bundle of rights framework" developed by Theis et al. (2018) which assesses who has the right to use or operate a technology (Use rights), who has the right to make decisions on use (Management rights), who controls the outputs or profit generated (Fructus right) and who has the right to lease or sell the technology (Alienation rights).[103] While household decision-making processes vary highly by region and context, it has three overarching implications for adoption or non-adoption of new agricultural technologies.

Box 6: Female Vs. Male Headed Households.

Gendered constraints in technology adoption vary for women in male headed households and women in female headed households. Female heads of household face financial and labor-related constraints to purchasing a new technology; but have greater household decision making power on technology adoption. In contrast, although women in male-headed households might have access to labor and relatively better financial resources, they may lack sufficient decision-making power to influence the household decision to adopt a certain technology.

Source: Theis et al. (2018)

Firstly, intra-household power relations can influence who perceives value and makes decisions on adoption.[104] Perceived value of a technology influences adoption decision. Value is dependent on whose needs are being met or on the ability to reap immediate benefits from use in terms of income generated, cost reduced, time saved, or labor conserved.[105] A study on improved cookstove adoption found that women users were more

[98] Van Eerdewijk & Danielsen (2015); Doss (2001)
[99] Ragasa (2012)
[100] FAO (2023)
[101] Ragasa (2012)
[102] Vemireddy & Choudhary (2021)
[103] Theis, S., Lefore, N. et al. (2018)
[104] Theis et al. (2018)
[105] Kohl & Foy (2018); Manfre et al. (2017)

motivated to adopt clean cookstoves since they suffered from both the short and long-term consequences. However, primary male decision makers controlled the household budget and undervalued the benefits of the improved cookstoves resulting in non-adoption.[106]

Secondly, intra-household power dynamics can affect demand-articulation for mechanization.[107] Gendered division of labor influences the adoption and use of mechanization; and women's labor is often not recognized or their needs for mechanization are not viewed as urgent or important. Additionally, due to a variety of reasons, women tend of have weaker bargaining power in the household affecting their ability to articulate demand for mechanization of activities.[108] A CYMMIT project promoted Mechanical Rice Transplanters (MRTs) in rice-producing areas of India where manual rice transplanting task was primarily performed by women. Manual rice transplanting is a highly labor-intensive and arduous task with reported health consequences and MRTs offered an increase agronomic efficiency, reduction in the time required to transplant seedlings, saved labor costs (if using hired labor), and reduced drudgery of women in the family who participated in transplanting. The study found that MRT adoption decision was based on the household head's preferences, and reflected perceptions of whose time and labor reduction was viewed as valuable. Although the women in households that used family labor or hired labor valued the MRT disproportionately more than the men, women's intra-household bargaining power relative to men's was too weak to affect the choice to adopt MRT.[109]

Thirdly, intra-household power dynamics affects who benefits from mechanization. Even when conditions for technology adoption are optimal, women may not benefit long-term from the technology. A study on small scale solar irrigation technologies in Ethiopia, Ghana, and Tanzania found that despite designating women as owners of the equipment, women had little control over the use and benefits of the technology due to household beliefs about who can own and operate assets.[110] Moreover, once the irrigation equipment was shown to be profitable, men took over the use and management of the technology. This reveals the importance of not only addressing women's access to technology but also evaluating if they are benefiting from the same both in the short and long term. Here benefits can include reduced time, labor, or income generated.

2.3.4 Address Unintended Consequences

New technologies introduced through agricultural development programmes can mitigate or reinforce gender inequality. An often-cited concern is mechanization's impact in replacing rural agricultural labor. Three patterns emerge from studies that document the impact of mechanization on agricultural labor.

Firstly, mechanization can disrupt gendered labor patterns. Since gender norms determine women and men's agricultural tasks, mechanization affects men and women's labor differently. The gendered effects are both direct (dependent on which agricultural operations are mechanized) and indirect with spillover impacts on other tasks.[111] There have been numerous studies over the years documenting a gendered shift in agricultural labor induced by the uptake and scaling of agricultural mechanization. For example, in India mechanization has led to significantly greater decline in women's labor rather

[106] Miller & Mobarak (2013)
[107] Badstue et al. (2020)
[108] Daum (2023)
[109] Farnworth et al. (2021); Gulati et al. (2019)
[110] Theis, S., Lefore, N. et al. (2018)
[111] Afridi et al. (2020)

than men's, with one study estimating a 22% fall in women's agricultural labor from 1999 to 2011.[112] The increase in mechanized tilling resulted in reduced demand for labor in weeding, a task often undertaken by women leading to a loss of women's livelihood. Additionally, a recent International Food Policy Research Institute (IFPRI) study in eight countries in Asia and Africa found that the use of tractors and or combine harvesters by a household resulted in a higher labor shift by female members from farm activities to non-farm activities than by male members.[113]

Secondly, the effects of mechanization induced labor disruption are worse for farmers who are dependent on manual labor as a source of livelihood. Women and men in low asset households face more difficulties in finding alternative income sources. Often this includes landless laborers, widows, women household heads, women from ultra poor backgrounds or from lower castes.[114] For example, introduction of mechanized rice mills replaced women's work in hand pounding rice in Bangladesh. This mostly affected women who could not leave their homesteads due to socio-cultural norms and resulted in the loss of an important source of income.[115] Similarly, in Viet Nam, the introduction of the drum seeder caused 97% of landless women to lose their work in gap filling and weeding, and 43% had difficulties in finding alternative sources of income.[116] Another study in Bangladesh and Myanmar found landless women dependent on manual mung bean harvesting work for their income were affected by increasing harvesting mechanization. The women were further limited by gendered restrictions in their mobility, their role as family caregivers, and social norms that dictated men and women's tasks and options for alternative employment.[117]

Thirdly, positive implications of mechanization are influenced by women's mobility and access to alternative employment and the availability of the same. One study showed that if the women whose labor is replaced by mechanization came from empowered households they shifted from farming to non-farming activities demonstrating agency in their livelihood choices.[118] For example, in the Philippines, the introduction of mechanical threshers resulted in an initial loss of women's work, but eventually increased opportunities for women in transplanting, weeding, and harvesting.[119] Gender intersecting with caste structures can also impact potential employment opportunities for women. A study in India found that scheduled caste women were able to better compensate for the employment loss from mechanization since they had more flexibility in seeking alternative work. However, they still bore the brunt of labor loss since alternative work was hard to find, and for generations they have been dependent on paid fieldwork for their livelihoods.[120]

Preemptive measures to monitor technology impacts

It is important for programmes, institutions, and governments to be aware of unintended gendered consequences and address any potential negative impacts that can arise from introducing new mechanization through policy or programmatic interventions. It starts with the need to **intentionally target women** by setting goals or quotas for reaching a specific percentage of women farmers. Programme evaluations should go beyond collecting sex-disaggregated data that measures the number of women who have received training and instead evaluate benefits and impact on women and the household.[121]

[112] Ibid.
[113] Takeshima & Diao (2021)
[114] Daum (2023); FAO (2023)
[115] Farnworth et al. (2020)
[116] Paris et al. (2005)
[117] Farnworth et al. (2020)
[118] Paris (1998)
[119] Ibid.
[120] Farnworth et al. (2022)
[121] Ragasa (2012)

Next, care needs to be taken that mechanization that is intended to reduce drudgery or improve socio-economic outcomes for women does not push women out of the sector or remove their opportunities for income generation.[122] Since technologies can improve or worsen gender relations it is important to **monitor the short and long-term impacts of technology** on both male and female users and non-users. Evaluations should assess changes that occur to men and women's time and labor with the adoption of a technology, and how it might vary between users and non-users. It is also important to assess who benefits from a technology and if there is a loss of income-generating opportunities for certain sub-sections of populations when a paid task is eliminated by mechanization. Table 1 provides a list of relevant tools that have been tested with diverse stakeholders and can be used to monitor gender - technology impacts.

Additionally, mechanization scaling programmes need to develop comprehensive approaches that close gender gaps through adequate resources, skills and capacity while improving women's agency. Programmes that focus on **reskilling, provision of off-farm work opportunities and social protection measures** for women can be very beneficial.[123] Mechanization programmes can build capacity of women to provide services related to the technology where they have been under-represented and create new income-generating opportunities that provide relatively higher returns.[124] For example, Barefoot College, a non-profit organization, trains and equips rural women to be solar engineers called as "solar mamas" to build solar kits, install, and maintain solar panels and batteries. The women earn income by setting up solar systems in their villages providing off-grid renewable source of energy to their communities. The programme also uses visual learning tools like color-coded pictures and manuals to reach low literate women complex electrical circuiting and other technical details.[125]

Finally, mechanization scaling programmes should work in partnership with the private sector to develop women's skills in equipment manufacturing, maintenance, repair. For example, a number of private sector agricultural and automobile manufacturing companies in India are investing in training and upskilling women in core manufacturing skills along entire production lines which were formerly considered "male" jobs.[126] Other innovative upskilling examples include facilitating the development of entrepreneurial models where women run mechanization service provision businesses. This is explained in further detail in Section 3.1.

[122] ICIMOD (2021)
[123] FAO (2023)
[124] Takeshima & Diao (2021)
[125] Castonguay (2009); Magistretti (2019); Mininni G. (2022)
[126] Dhamija (2023); The Hindu Bureau (2023)

III. Integrated Approaches to Scale Gender-Responsive Mechanization

In order to develop and scale sustainable agricultural mechanization that truly benefits smallholder women farmers we need to develop holistic and integrated solutions. This requires an understanding of the complex ecosystem of actors and services and integrating them at a market level, institutional level, and a policy enabling environment level.[127] A holistic solution needs to look at constraints on both the supply and demand sides of technology and use a systems-perspective to ensure that technologies generated and disseminated respond to farmers' and target clients' demands and needs.

3.1 Market-Based Approaches

3.1.1 Mechanization Service Provision

Small scale mechanization requires significant capital investment for specific agricultural tasks (such as harvesting) and can remain out of the price range for both male and female smallholder farmers even with access to credit or government subsidies. Moreover, in some contexts, cultural norms can restrict women's ownership and operation of mechanized implements or women themselves are not interested in owning or operating machines.[128] To scale benefits of mechanization for women famers in different contexts, we need to pivot our focus from women's technology acquisition as the end goal to instead targeting women as "customers" who can still benefit from mechanization without requiring formal ownership or operation.[129]

In Asia, fee-for-service or custom hiring mechanization service providers (MSP) are making agricultural mechanization more accessible to smallholder farmers as rural labor availability declines. MSPs run successful enterprises by owning multiple agricultural equipment and providing timely services such as planting, transplanting, harvesting, etc. For instance, in Myanmar, MSPs have made the use of tractors for land preparation and combine harvesters for harvesting/threshing equitable and inclusive for small and medium farmers.[130]

Typically, MSPs tend to be medium-large landholding male farmers who use equipment for their own farms in addition to providing fee for hire services. The low-cost hiring of services reduces smallholder farmers' individual cost burdens of purchasing, owning, and maintaining machines.[131] In some cases, wives of the male MSP play a key behind-the-scenes role in managing financial transactions and accounting, and keeping track of customer requests while their husbands were not present. Additionally, they advertised mechanization services to other farmers through their social networks, brought fuel for the machine, prepared, and brought food for operators (whilst in the field) and cleaned machinery.[132]

Despite the increasing number of female-headed

[127] Ragasa (2012)
[128] Jones et al. (2023)
[129] Theis et al. (2019); Jones et al. (2023)
[130] Daum (2023)
[131] Loon (2020)
[132] Theis, Sultana, et al. (2018)

households resulting from male outmigration, there is a gap in women accessing mechanization services through MSPs. Women head of households face social barriers in directly contacting, negotiating prices, and dealing with MSPs. Women's farms also tend to be prioritized less than men's since MSPs prioritize larger farms, contiguous plots of land, and well-known farmers who pay in cash.[133] In Bangladesh, women customers overcome socio-cultural constraints in accessing MSPs by approaching the wives of the service provider to request mechanization services either in person or over the phone.[134]

Approaches to scale women farmer's access to mechanization service providers

To ensure that more women farmers can benefit from mechanization services offered, programmes need to work with current MSPs to make a business case for gender equity – i.e., addressing mechanization needs of women clients will provide new business opportunities. Additionally, programmes need to sensitize male MSPs on the role their spouses play in jointly managing the business and further build their capacity to engage in the business. Such measures can ensure mechanization services are accessible for more women, strengthen women's business skills, and contribute towards transforming gender dynamics.[135]

Secondly, where opportunities exist women farmers should be encouraged to start their own MSPs enterprises. For instance, in Cambodia, women are engaged in solely managing MSPs such as tilling and planting. The women MSPs do not operate the machines themselves but hire operators who provide services and maintain the machines.[136] Programmes can encourage the ownership of such enterprises through the provision of business training, subsidies and access to credit, and market connections to purchase machines. Moreover, exposure visits to meet other women entrepreneurs involved in service provider businesses can increase women's confidence to start a business, as well as show men the benefits of women's involvement.[137]

3.1.2 Farmer Groups

Well-functioning Farmer Producer Organizations (FPOs), farmer cooperatives, Self Help Groups (SHGs), Farmer Organizations (FOs) or other collective forms can benefit women smallholder farmers by providing key linkages across the value chain including access to resources, assets, information, credit, and better market linkages. FOs can not only serve as a platform for resources and information but also help rural women overcome social constraints and empower women through leadership opportunities and skills development increasing their agency and confidence.[138]

FOs are an effective platform for provision of information, advisory and extension services on new innovations. Especially in Asia, collectives that intentionally target women, provide access to information, training and resources enabling inclusive agricultural technology adoption.[139] In Bangladesh, there is strong evidence of the long-term impact of group-based dissemination of agricultural technologies. For example, the Egiye Jai and Nigera Gori (which translate to "Move Forward" and "We Build It Ourselves" in Bengali), implemented by Catholic Relief Services and Caritas Bangladesh, increased women smallholder farmers access to improved technologies and

[133] Ibid.
[134] Jones et al. (2023)
[135] Theis et al. (2019)
[136] Jones et al. (2019)
[137] Theis (2019)
[138] Ragasa (2012)
[139] Rola-Rubzen et al. (2020)

information through a cluster-level training approach. Through demonstration plots and field days, the cluster approach encouraged women farmers to participate in agricultural training programmes and overcome the limitations of physical mobility outside of their communities. The clusters enabled women to share knowledge and experiences with others in the same area leading to the replication of improved agricultural practices.[140]

FOs can fill the gap in women's access to mechanization through group ownership of technologies, help increase women's long-term assets and strengthen their social capital.[141] Through government or donor initiatives, FOs have access to large scale mechanization such as reapers, combine harvesters and planters and run service mechanization enterprises with their members through in-house custom hiring centres. Such services are provided to members at a low cost with the help of hired male operators and profits generated are either invested back into the group or are distributed amongst members. For example, FAO's Missing Middle Initiative works with both women's and mixed FOs to provide access to external financing, improve their organizational management and generate income through provision of mechanization services and post-harvest operations.[142] Similarly, the Cereal Systems Initiative for South Asia Mechanization Extension Activity (CSISA-MEA) trains women farmers and women's groups to manage machinery-based businesses through technical and business training trained such as raising rice seedlings to be used with the mechanized rice transplanter.[143]

Finally, **FOs play a key role by linking the supply and demand side of technology, advisory services, and market access.**[144] FOs can organize considerable networks capable of effectively demanding improved technologies and services. For example, in India, a women's SHG "Dooni" provided a platform for women members to pool resources, raise funding from financial institutions and seek assistance from the government or charities to purchase solar refrigerators that helped the group reduce milk wastage and increase profits.[145]

3.2 Building Institutional Capacity to Integrate Gender

3.2.1 Organizational Capacity

Gender equitable mechanization at the field-level needs to first start with gender equity at the institutions responsible for research, design, extension, and policy decisions at the leadership and implementation levels.

Organizational gender policy and gender strategies should be developed as key guiding documents. Institutional gender policies, gender strategies or Diversity, Equity and Inclusion indicators can clarify overarching values and develop measurable metrics.[146] For instance, a mechanization organization's gender policy could include a "do no harm" approach by committing to conduct regular gender evaluations on technologies. Gender policies can also include quotas for reaching a specific percentage of women farmers across all programmes and operational priorities such as ensuring gender balance in project staffing. Helpful resources include the UN Women's Gender

[140] Lee et al. (2022)
[141] Peterman et al. (2010)
[142] Global Agriculture and Food Security Program report
[143] Khan (2022)
[144] Ragasa et al. (2014)
[145] Shetty (2018)
[146] Zheng (2023)

mainstreaming guide and the Australian government's Gender Strategy Toolkit.

Leadership buy-in is critical to increasing gender-responsive programming; and it is important to build capacity of leadership to better integrate gender into programming. While most leaders might be aware of the need to better integrate gender considerations into programming, both men and women leaders lack practical know-how, skills, and competencies to do so.[147] Therefore, practical training is needed on topics at both an organizational level and programmatic level. Organization level training can include topics such as overcoming unconscious bias in hiring, promotions, and addressing workplace situations.[148] Programmatic level training can include topics such as key gender issues within scaling agricultural technologies. Leadership buy in is also important to address low levels of funding for research that explicitly target gender considerations in agriculture.

3.2.2 Research and Academic Institutions

The representation of women in decision making positions in research and academic institutions can be an important avenue to make agricultural policies and technologies more gender responsive. However, women are underrepresented as scientists, educators, and researchers especially in agriculture and engineering. On average less than one out of four agricultural researchers is a woman, and though the share of women is increasing it declines with seniority.[149] Addressing the gender balance in hiring can ensure that women's voices are heard more in critical research, policy and decision-making processes resulting in better outcomes for women smallholder farmers.[150] To achieve this, we need to -

Firstly, implement programmes that **develop a pipeline of qualified women professionals** to join government, science, and research organizations. The supply of women graduates and professionals in the field of agriculture and sciences is limited in many countries due to the lack of opportunities for girls, social norms that prevent them from going to school after a particular age, barriers in entering sciences and technical fields, and social pressures against pursing advanced degrees.[151] Placing an emphasis on women's education, including incentives and scholarships for women in science and policy can ensure a pipeline of well-qualified women candidates for senior positions in public and private organizations. A success story is the African Women in Agricultural Research and Development (AWARD) programme, a career development programme that targets African women scientists working in agriculture and food systems to build their capacity and provide opportunities. The programme has used successful intervention strategies such as a renowned fellowship program, fostering networks, a mentoring culture, and incentivizing cross-institutional collaboration and research.[152]

Secondly, **hire women in agricultural research, especially at senior leadership levels**. Traditionally agriculture and engineering tend to be male dominated industries with just 38% and 28% women employees respectively.[153] When women enter research organizations they are constrained by a lack of balanced gender representation in recruitment and promotion committees, work–life balance challenges owing to the prevailing perception of a woman's role as a mother, and covert discrimination in organizations.[154] Successful

[147] Emerson (2017)
[148] Ibid
[149] Quisumbing et al. (2014)
[150] Ragasa et al. (2014) Offerman (2020); Wahman et al. (2021)
[151] Ragasa; Quisumbing et al. (2014)
[152] AWARD (2017)
[153] International Labor Organization (2020); World Economic Forum (2016)
[154] Meinzen-Dick et al. (2010)

measures that can be put into place to reach a gender parity includes having a leadership quota system to hire women in mid and senior level positions, addressing barriers female employees might face in growing into senior leadership roles, and instituting policies such as parental leave and flexible working arrangements.[155]

Finally, it is important to **engage men in understanding and promoting gender focused agricultural research and design**. Greater attention to increasing gender balance in staff should also be coupled with training for male researchers to ensure that they can respond to the needs and priorities of both women and men farmers. Additionally, developing incentives and accountability measures among researchers to respond to the problems faced by women farmers can also help close the gender gap.

3.2.3 Extension Agencies

In addition to ensuring gender sensitive training practices, it is important to address a key gap in extension and advisory services by both building capacity of existing staff to better reach women farmers and recruiting more women into the field.

Extension and advisory services staff need to be equipped with skills to better reach women farmers. This includes basic training on gender issues within extension and advisory services, knowledge of best practices, and proven tools and techniques to reach women farmers. For example, extension agents should have knowledge participatory tools and skills to manage diverse cultural contexts, and power dynamics; along with knowledge of time and labor-saving technologies that can benefit women and men. Both male and female agents should also be equipped to work better with women farmers through training in extension methods and communication skills suitable for female farmers.[156] Training topics can include understanding men and women's roles in household production systems and identifying gender considerations within agricultural value chains.[157] In addition, extension and advisory services agents should be presented with monthly targets and incentives to reach women farmers which can encourage staff to seek out farmers women farmers who might not be easily accessible but need advisory services.[158]

In most countries extension and advisory services tend to be staffed predominantly by men. In some contexts, female extension agents can be more effective in reaching women by overcoming conservative social norms, interacting with women farmers in their homesteads and tapping into women-specific networks.[159] It is important for extension and advisory services agencies to review hiring practices, set quotas and hire women extension agents. However, there are known challenges in recruiting that need to be addressed including safety issues while working in remote areas, inadequate housing or provisions for families, and access to transportation.[160] Care must be taken to not marginalize women agents, to ensure workplace safety free from harassment and provision for advancement is also key to encourage women as female extension agents.

The Agricultural Technology Management Agency (ATMA) in India is overcoming shortage of women extension officers by mandating that women need to make up 30% of the governing board of service delivery organizations.[161] In Cambodia, a multi-stakeholder collaboration with the Conservation

[155] Krivkovich et al. (2022)
[156] Quisumbing et al. (2014)
[157] Henderson & Colverson (2016)
[158] Berger et al. (1984)
[159] Ragasa et al. (2014)
[160] Manfre et al. (2017)
[161] World Bank (2009); Manfre et al. (2017)

Agriculture and Sustainable Intensification Consortium, the General Directorate of Agriculture and the Royal University of Agriculture intentionally set out to hire the women extension agents. The female agents were trained in a variety of techniques, provided with housing close to their work area, and were provided with motorcycles to travel to different farmers homes.

IV. Annex

4.1 Tools to Help Guide Researchers, Technology Developers, and Policymakers Assess, Design and Scale Gender-Responsive Agricultural Technologies and Mechanization

Table 1

Tool	Developer	Purpose
Gender responsive mechanization needs assessment	FAO	Questionnaire to assess contextual gendered needs for mechanization and guide the selection and promotion of mechanization that responds to the needs of women farmers for their benefit and empowerment
Checklist of contextual influences: effective international engineering	A. Witmer-Perry	Assess contextual influences broadly.
Participatory Rural Appraisal	R. Chambers	Assess gender impacts within scaling innovations. Useful data collection tools include labor mapping or daily time use analysis, resource mapping, participatory social mapping, and analysis of difference. (McGuire 2022)
Assessing How Agricultural Technologies can Change Gender Dynamics and Food Security Outcomes	Cultural Practice /INGENAES	Framework that considers the social context of the agricultural technologies and the specific challenges that women and men farmers face in using the technology. Focuses on time and labor; food availability, access, quality, and safety; and income and assets
Guidance for inclusive small scale irrigation technologies	International Food Policy Research Institute / ILSSI	Questions to assess gender dynamics in irrigation in a specific context. Can be used to collect data at any stage of technology development to inform design, dissemination, and adoption of technologies
Women's Empowerment in Agriculture Index (WEAI)	International Food Policy Research Institute	Provides indicators that tracks gender equality and measure empowerment, agency, and women's inclusion in the agricultural sector. WEAI has different variations depending on users' needs such as the PRO-WEAI for projects or the A-WEAI for a shorter tool
GenderUp: A gender-responsive method to	CGIAR Research	Improve agricultural innovation scaling strategy by anticipating unintended negative consequences for

scale	Programme on Roots Tubers and Bananas	different groups in society. Can be used alongside Scaling Readiness tool.
Reach Benefit Empower framework	International Food Policy Research Institute	Clarifies project objectives by distinguishing between approaches that reach women participants, benefit women by improving circumstance, and empowering women.
Gender in Agricultural Mechanization: Key guiding questions from design to impact	GENNOVATE	Simple guiding questions to consider the gender implications of interventions involving farm machinery

4.2 Labor Saving Technologies and Mechanization

Table 2

Note – this list only includes technologies tested or suggested for an Asian context

Production stage	Equipment	Country tested	Source
Land preparation	Mini-tiller & attachments	Nepal	Justice, S. et al., (2022)
	Power tiller (Two wheel tractor)	Nepal	Justice, S. et al., (2022)
	Hand ridger	India	S. P. Singh et al. (2006); Vemireddy (2021); Mehta et al., (2018)
	Seed treatment drum		
Planting	Drum seeder	Nepal; India; Viet Nam	Justice, S. et al., (2022); Mehta et al., (2018); Paris et al., (2011)
	Manual seed driller	India	ICAR (2018)
	Manual rice transplanter	Nepal	Justice, S. et al., (2022); Mehta et al., (2018)
	Rotary dibbler	Nepal; India	Justice, S. et al., (2022); Mehta et al., (2018)
	Naveen dibbler	India	S. P. Singh et al. (2006); Vemireddy (2021); Mehta et al., (2018)
	Jab planter	Nepal	Justice, S. et al., (2022)
	Manual vegetable transplanter	Nepal	Justice, S. et al., (2022)
	Push row planters	Nepal	Justice, S. et al., (2022)
	Seed cum fertilizer drill attachment	Nepal	Justice, S. et al., (2022)
	Direct seeder	Nepal; India	Justice, S. et al., (2022); Gartaula et al., (2020); Vemireddy (2021)
	Mechanical rice transplanter	India; Bangladesh	Gartaula et al., (2020); Vemireddy (2021);
Weeding	Power weeder	Nepal	Justice, S. et al., (2022)

	Push row weeder	Nepal	Justice, S. et al., (2022)
	Rotary weeder (cono weeder)	Nepal	Justice, S. et al., (2022); Mehta et al., (2018)
Fertilizer application	Hand cranked seed and fertilizer spreader	Nepal	Justice, S. et al., (2022)
	Fertilizer broadcaster	India	Mehta et al., (2018)
Irrigation	Irrigation pump sets	Nepal	Justice, S. et al., (2022)
	Micro-irrigation (drip or sprinkler)	Cambodia	Grassi et al., (2015); Edralin (2014)
Harvesting	Walk-behind self-propelled reaper	Nepal; Bangladesh	Justice, S. et al., (2022); Theis et al. (2019); Vemireddy (2021)
	Two-wheel tractor reaper / harvester	Nepal	Justice, S. et al., (2022)
	Potato digger for mini tiller	Nepal	Justice, S. et al., (2022)
	Power brush cutter/ harvester	Nepal	Justice, S. et al., (2022)
Post-harvest	Rice open drum thresher	Nepal	Justice, S. et al., (2022); Mehta et al., (2018)
	Mobile thresher	Nepal	Justice, S. et al., (2022)
	Portable axial flow thresher	India	Pingali (2007); Vemireddy (2021)
	Maize de-husker with sheller	Nepal	Justice, S. et al., (2022)
	Maize sheller (rotary or tubular)	Nepal, India	Justice, S. et al., (2022); S. P. Singh et al. (2006); Vemireddy (2021); Mehta et al., (2018)
	Combined rice de-husker and flour feed mill	Nepal	Justice, S. et al., (2022)
	Portable rice mill	Bangladesh; Viet Nam; Nepal	Paris et al., (2017) Hartl (2010)
	Motorized grain cleaner / sorter		Grassi et al., (2015); Mehta et al., (2018)
	Solar dryers		Grassi et al., (2015)
	BAU-STR grain dryer	Bangladesh	Alam (2019); Jones (2019)
	Ground nut decorticator	India	Mehta et al., (2018)
	Paddy winnower	India	Mehta et al., (2018)
	Powered fodder chopper	Nepal	Justice, S. et al., (2022)

Other databases include FAO' Technologies and Practices for Small Agricultural Producers (TECA) database that has documented available technologies globally with a filter for women-friendly technologies and practices. www.teca.apps.fao.org

4.3 Gender Distribution of Agricultural Researchers in Asia

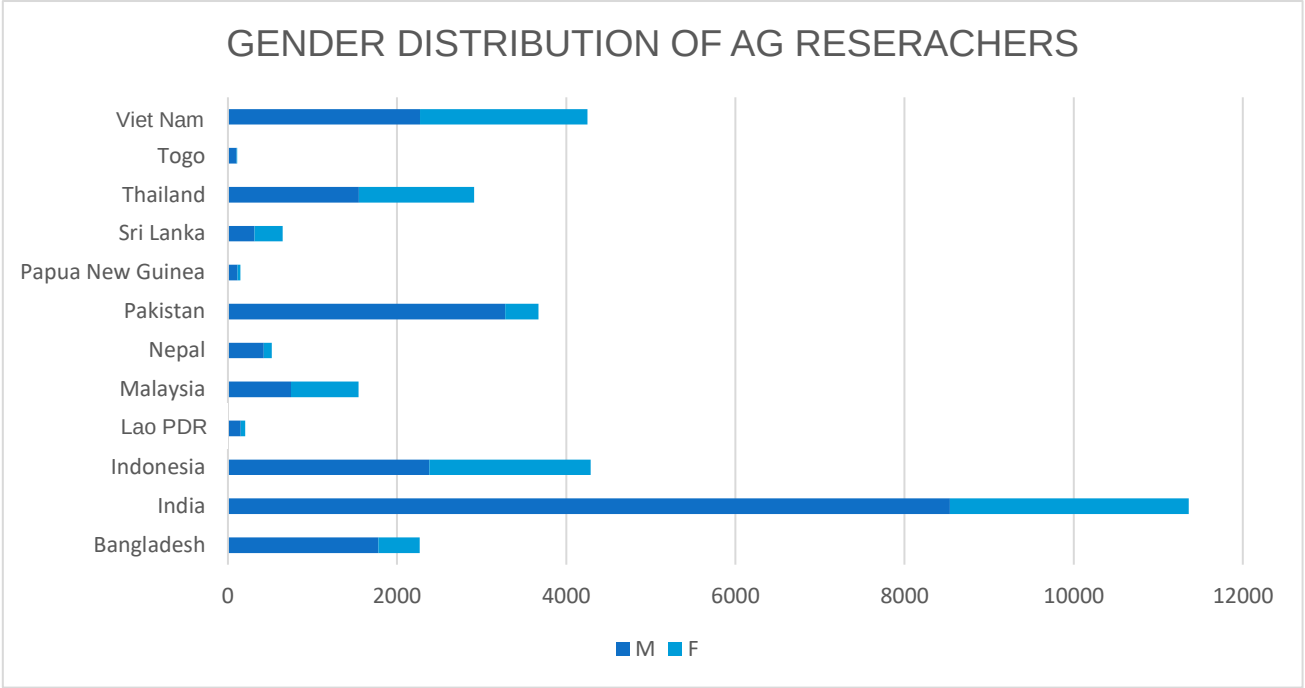

Figure 2 Gender Distribution of Agricultural Researchers. Source: Agricultural Science and Technology Indicators (ASTI) 2008-2017 data

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